Executive Summary from "Emission Reductions from Changes to Gasoline and Diesel Specifications and Diesel Engine Retrofits in the Southeast Michigan Area." Completed by Air Improvement Resource, Inc. for SEMCOG's Fuels Group. February 23, 2005.

**Emission Reductions from Changes to Gasoline and Diesel Specifications in the Southeast Michigan Area**

# 1.0 Executive Summary

## Background

On April 15, 2004, the U.S. Environmental Protection Agency (EPA) finalized its list of 8-hour ozone nonattainment areas. Eight counties in Southeast Michigan were designated as a "moderate" nonattainment area. Under EPA rules, moderate areas have until 2010 to attain the 8-hour ozone standard. Moderate areas must also implement a vehicle inspection program if they do not already have one, and reduce ozone precursors by 15%.

Subsequently, the Southeast Michigan Council of Governments (SEMCOG) and the Michigan Department of Environmental Quality (MDEQ) requested a reclassification from the EPA to a marginal nonattainment area. EPA approved this request on September 15, 2004. Marginal areas are not required to implement vehicle inspection programs or implement a 15% reduction in emissions by 2010, but they must attain the ozone standard by 2007. SEMCOG's and MDEQ's request for reclassification did not change their commitment to attain the standard, but it did give them additional flexibility with regard to the control strategies it can pursue in order to meet the standard.

To ensure that the Southeast Michigan area attains the ozone standard as soon as possible, SEMCOG has been studying ways to reduce ozone precursors. As a part of this effort, it initiated a study of the emission reduction potential of different gasoline and diesel fuel formulations. SEMCOG formed a stakeholder group consisting of representatives with expertise from the oil industry, automobile industry, the Michigan Department of Agriculture and the Michigan Department of Environmental Quality to provide guidance to the study. SEMCOG contracted with Air Improvement Resource, Inc. (AIR) to quantify emission reductions that would result from various changes to fuels.

## Method

In order to focus the study, the stakeholder group agreed to evaluate the emission reduction benefits of the following list of fuels and related controls. The options on the list were designed to provide a broad perspective of the emission reduction potential of various fuels. Nothing should be presumed about the feasibility or desirability of any option simply because it was analyzed in this study. For instance, several of the fuels studied are currently only available in California, while several others are not manufactured or used anywhere in the U.S.

Gasoline

- California reformulated gasoline (Ca RFG)
- Federal reformulated gasoline (RFG)
- Lower sulfur gasoline (10 ppm average)
- Lower volatility gasoline (limit of 7.0 psi Reid vapor pressure (RVP))
- A range of ethanol market penetrations (0 and 100% of a 10% ethanol blend)

Diesel

- California (CARB) diesel
- High cetane diesel
- Biodiesel (5% and 20%, or B5 and B20)
- In-use diesel engine particulate matter (PM) retrofits

The stakeholders desired that the study be as comprehensive as possible which, in some cases, included assessments of the same fuel using different modeling tools. These include EPA's MOBILE 6.2, NONROAD, and Complex models, as well as California's Predictive Model. The use of these different models allowed for a more complete perspective and provided users the opportunity to evaluate results in light of each model's strengths and weaknesses.

For each of the gasoline and diesel scenarios, expected fuel properties in Southeast Michigan were determined for the 2007 and later timeframe, taking into account controls required by the EPA. In the case of the gasoline scenarios, these fuel properties were used in the Complex and Predictive Models to estimate the percent change in exhaust emissions of volatile organic compounds (VOC), oxides of nitrogen (NOx), carbon monoxide (CO), and fine particulate matter (PM2.5) from the Michigan baseline gasoline. These percent reductions were then applied to MOBILE6.2-generated exhaust emissions to estimate the changes in exhaust emissions. Changes in evaporative emissions, except permeation impacts of ethanol, were estimated directly with the MOBILE6.2 model. Emissions from off-road equipment and off-road vehicle sources were estimated with the EPA NONROAD model.

A recent study by the Coordinating Research Council (CRC) indicates that ethanol increases permeation of VOC emissions from non-metal fuel systems found on on-road and off-road vehicles, other off-road equipment, and portable gasoline containers. Estimates of ethanol blends on permeation emissions from these sources were incorporated in this study, and these estimates utilized these CRC data in making these estimates.

## Baseline Inventory

Baseline inventories for on-road and off-road sources are shown in Table ES-1. The table shows that VOC emissions from on-road sources will decline by 71 tons per day (40%) from 2002 to 2007, and that NOx will decline by 184 tons per day (40%). There are also significant reductions of VOC and NOx from off-road sources. The CO inventory for on-road vehicles is projected to decline very significantly, but CO from off-road sources is projected to increase somewhat. The majority of the emission reductions shown in Table ES-1 result from the phasing-in of existing federal regulations.

| Table ES-1. Baseline On-Road and Off-Road Inventories for Southeast Michigan (Gasoline and Diesel – Tons per Summer Day) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | On-Road | | | | Off-Road | | | |
| Year | VOC[1] | NOx | PM2.5[2] | CO | VOC[1] | NOx | PM2.5[2] | CO |
| 2002 | 177 | 463 | 7.1 | 2412 | 66 | 69 | 6.1 | 1034 |
| 2007 | 106 | 279 | 4.2 | 1257 | 49 | 58 | 5.2 | 1119 |
| 2010 | 86 | 211 | 3.1 | 1094 | 40 | 48 | 5.1 | 1145 |
| 2015 | 62 | 114 | 2.0 | 906 | 35 | 40 | 5.1 | 1196 |
| 2020 | 54 | 71 | 1.6 | 848 | 35 | 40 | 5.3 | 1281 |

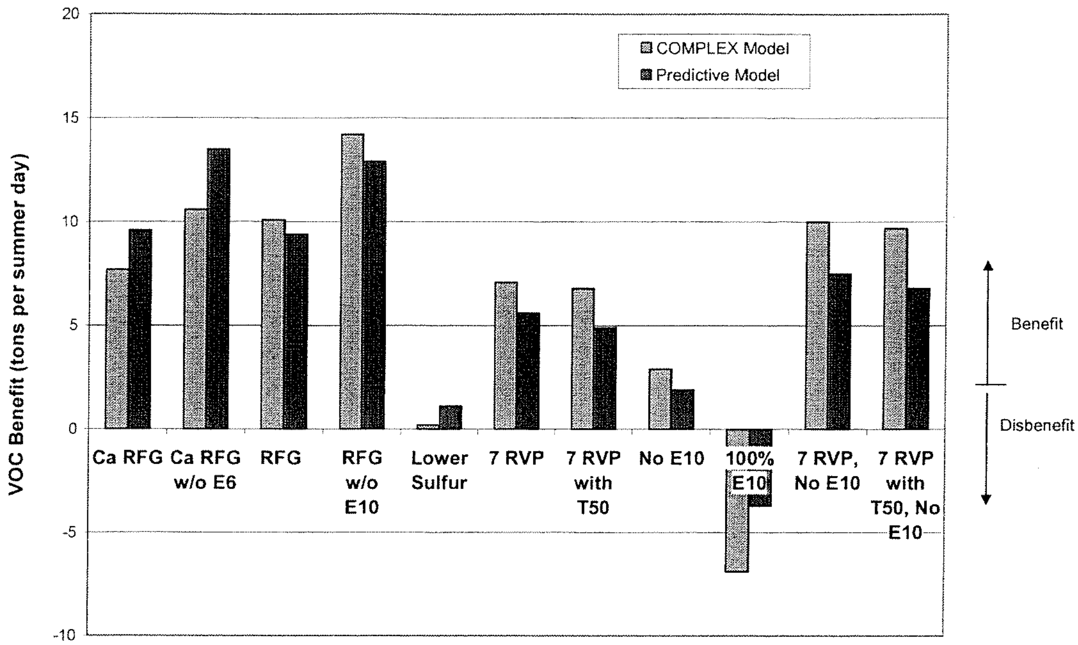
[1]Includes both exhaust and evaporative emissions but does not include any increase in permeation VOC emissions due to current ethanol market fraction of 25%.
[2]Exhaust emissions only

The VOC values in Table ES-1 do not include the increased permeation emissions from the portion of Southeast Michigan gasoline that contains ethanol (approximately 25%). At 25% market share, ethanol (E10) adds about 2 tons per day of VOC to the current inventory. If the ethanol market share were to increase from 25% to 100% (as assumed to be the case with Ca RFG or RFG), VOC permeation emissions would increase an additional 5.3 tons per day.

*Results of Gasoline Analysis*

The cumulative VOC and NOx benefits estimated in the study for the gasoline options are shown in Figures ES-1 and ES-2. Estimates are shown using two different models to predict exhaust emission changes - the EPA Complex Model, and the California Predictive Model. Results from the two models should not be averaged, they should instead be viewed as the range of likely benefits.

**Figure ES-1. Net VOC Benefits in 2007 - All Sources**
**(tons per summer day)**



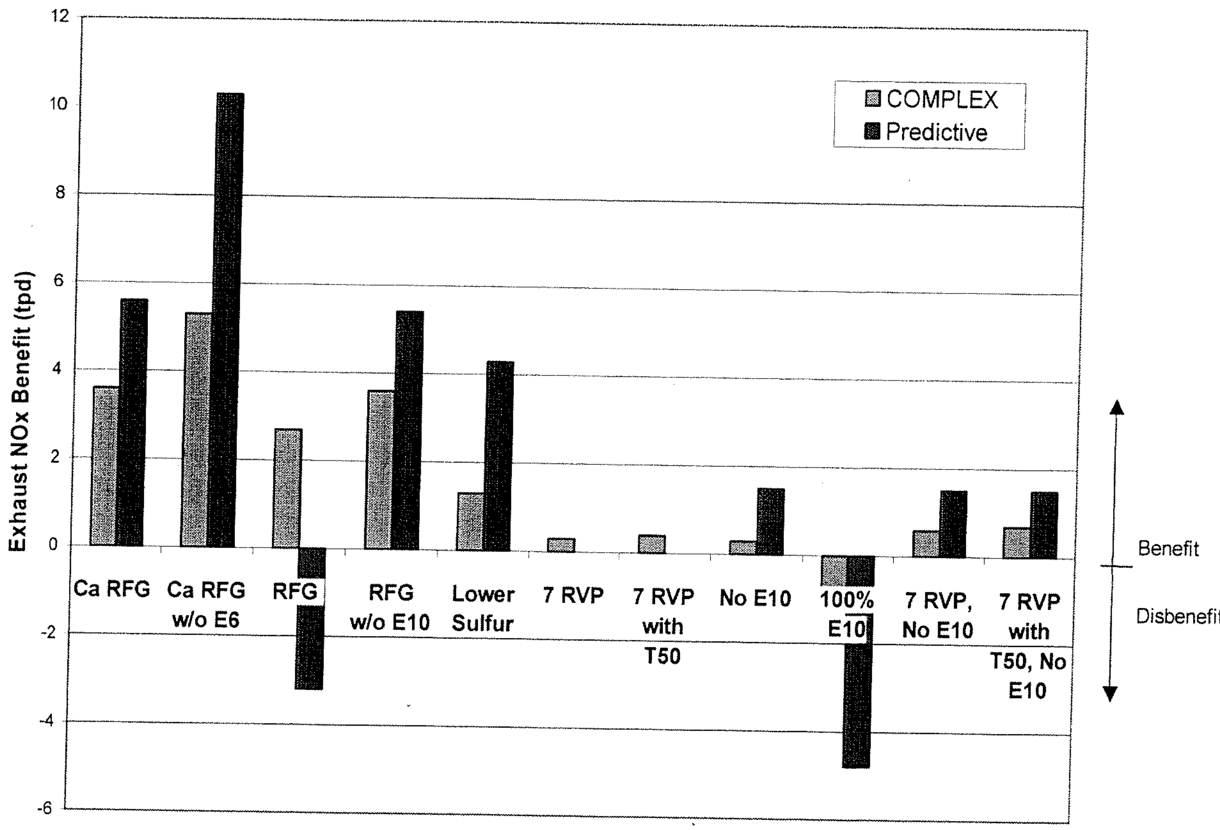

<u>Notes for Figure ES-1</u>
1. Includes all exhaust and evaporative effects, including ethanol permeation, where applicable.
2. Includes both on-road and off-road sources.
3. E6 and E10 refer to the volume percent of ethanol in the gasoline. E6 denotes a 6% ethanol concentration; E10 denotes a 10% concentration. 100% E10 denotes 100% market share of E10 fuel.
4. *7 RVP with T50* is a low volatility sensitivity case in which T50 is assumed to increase by 3°F as a result of the lower RVP.
5. The reduction benefit of lower volatility fuels is expected to be higher than shown above because the NONROAD model does not currently include hot soak and running losses, and these components would be reduced with lower volatility fuels.

## Findings and Observations Regarding Gasoline VOC Emissions:

- California RFG and Federal RFG provide the greatest VOC reduction benefits.
- The benefits of both RFG programs are reduced when ethanol is used, due to the increase in permeation VOC emissions caused by ethanol.
- Lower volatility fuels (7 RVP and 7 RVP with T50) also provide significant reductions, roughly half the benefit of reformulated gasoline.
- If the T50 level of lower volatility (7 RVP) fuel increases, the Predictive Model indicates the overall VOC benefit will be reduced.
- If ethanol were not used at all in Southeast Michigan (No E10 option), VOC emissions would be lower due to the elimination of ethanol-induced permeation and the reduced evaporative emissions due to lower average volatilities (ethanol currently receives a 1.0 psi waiver).
- The benefits of 7 RVP can be added to the benefits of no ethanol. The benefits of the combined options are a little less than the reformulated gasoline options.

- Retaining the current gasoline program, and increasing the ethanol market share to 100% (100% E10 option) shows a significant VOC increase due to increased permeation.
- The VOC benefits shown in all the lower volatility options in Figure ES-1 (Ca RFG, RFG, 7 RVP, and 7 RVP with T50) are understated because EPA's NONROAD model does not currently include hot soak and running losses, which are sensitive to fuel volatility changes Emissions from portable containers would also be lower. These benefits are expected to be significant.

**Figure ES-2. Net NOx Exhaust Benefits in 2007 - All Sources**
(tons per summer day)




Note: Figure ES-2 includes both on-road and off-road sources.

## Findings and Observations Regarding Gasoline NOx Emissions:

- Emission reduction benefits are highest for the two California RFG options.
- The Predictive Model estimates significantly greater NOx benefits than the Complex Model for the California RFG and Lower Sulfur options. In general, the Predictive Model is thought to provide better results as it uses more recent data on the impacts of sulfur on exhaust emissions.
- For Federal RFG, the Complex model predicts a NOx benefit, while the Predictive Model shows a disbenefit. While EPA and the California Air Resources Board both agree that

ethanol produces a NOx disbenefit in 1988-1995 light duty vehicles, only the Predictive Model currently takes this into account. Therefore, it is generally believed to provide better NOx emissions estimates for fuels containing ethanol. It should be noted that the Predictive Model also assumes an ethanol-related disbenefit for 1996 and newer vehicles. As of the writing of this report, it is our understanding that EPA believes the data on these vehicles is not conclusive.

- Both the RFG without ethanol and lower sulfur options show sizeable NOx benefits.
- Lower volatility fuels (7 RVP & 7 RVP with T50) have little or no effect on NOx.
- For the No E10 option, i.e. no ethanol would be used in Michigan, the Predictive Model shows a small NOx benefit.
- For the 100% E10 option, i.e. all Southeast Michigan gasoline would be 10% ethanol, the Predictive Model shows a significant NOx disbenefit.

It should be noted that, while most of the gasoline options tested could not be implemented in combination with one another, the 7 RVP and lower sulfur options are not necessarily mutually exclusive. In this case, the VOC and NOx emission benefits would be additive. In addition, while the CaRFG and RFG estimates without ethanol show favorable emission reductions, both fuels are required to include ethanol at a minimum concentration. CaRFG is currently not available outside of California.

Carbon monoxide (CO) inventory changes for the various gasoline fuel options are shown in Table ES-2.

**Table ES-2. Net CO Benefits - All Sources (tons per summer day)**

| Year | CaRFG | CaRFG w/o E6 | RFG | RFG w/o E10 | Low RVP, Low sulfur | 100% E10 | No E10 |
|---|---|---|---|---|---|---|---|
| 2007 | 125 | -83 | 273 | -83 | 0 | 265 | -83 |
| 2010 | 122 | -81 | 264 | -81 | 0 | 257 | -81 |
| 2015 | 123 | -81 | 266 | -81 | 0 | 260 | -81 |
| 2020 | 128 | -85 | 277 | -85 | 0 | 272 | -85 |

Notes for Table ES-2

1. Includes both on-road and off-road sources.
2. CO changes were estimated using EPA's MOBILE6.2 model, and adjusting the inputs for percent ethanol, ethanol concentration, RVP, and waiver status.

### Findings and Observations Regarding Gasoline CO Emissions:

- Ca RFG, RFG, and 100% E10 fuel scenarios would significantly reduce both on-road and off-road CO emissions.
- If ethanol were not utilized in Michigan (No E10 option), CO emissions would increase by roughly 80 tons per day.

Gasoline sulfur also affects CO, but this analysis did not estimate the impact of changes in gasoline sulfur level on CO emissions due to the lack of analytical tools. Both Ca RFG and the low sulfur fuel option would show an increase in CO benefits if this factor were included.

**Findings and Observations Regarding Other Gasoline Pollutants**

- California and Federal RFG, with or without ethanol, would provide significant toxic emission reduction benefits.
- Lower sulfur and lower RVP would provide some small toxic emissions benefits.
- California RFG and low sulfur fuel would provide some small exhaust PM2.5 benefits due to the reduction in sulfur levels from 30 ppm to about 10 ppm.

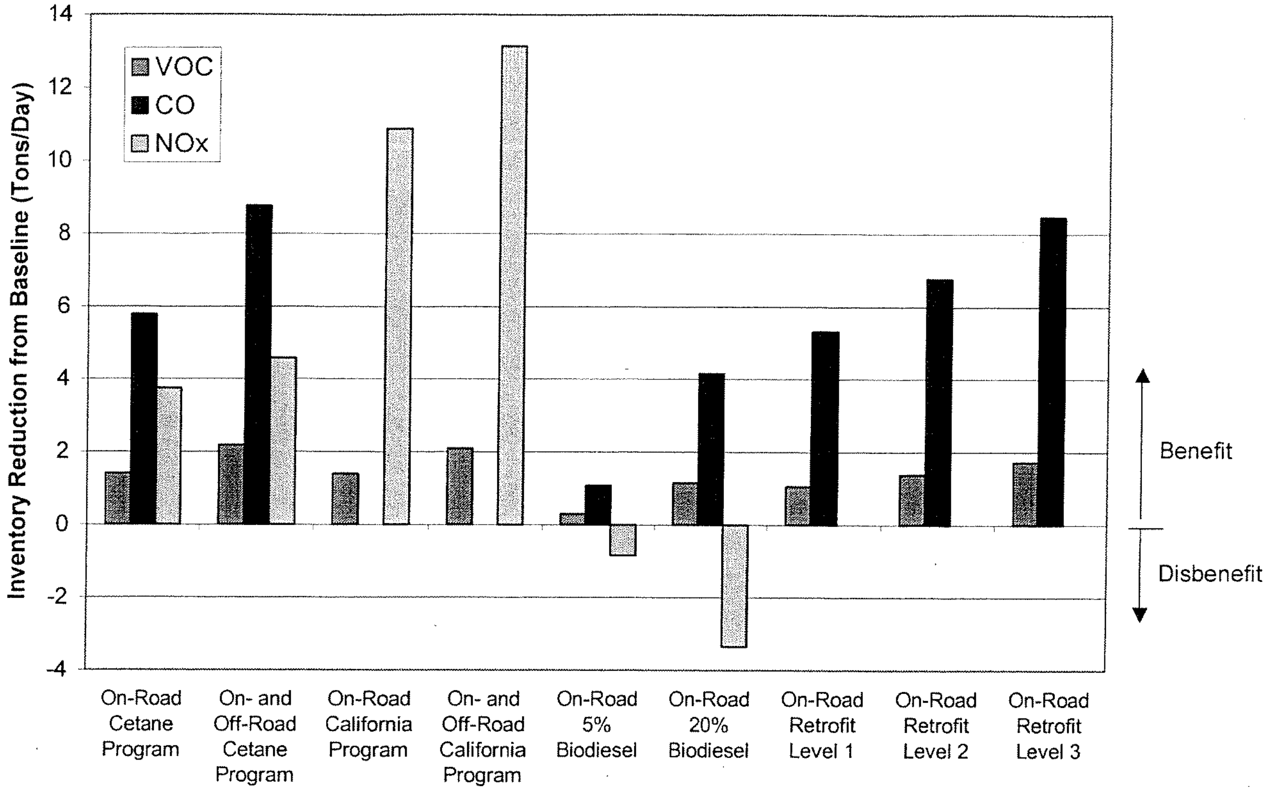
Results of Diesel Analysis

Figure ES-3 summarizes the 2007 VOC, CO and NOx emissions benefits from the different diesel programs.

**Findings and Observations Regarding Diesel VOC, NOx and CO Emissions:**

- As with gasoline, the emission reduction benefits of different diesel formulations vary significantly. The largest reductions come from California diesel, which yields over twice the NOx benefit of the high cetane option. However, California diesel is not manufactured outside of California, and the high cetane fuel studied is not manufactured or used anywhere in the U.S.
- VOC benefits range from 0.3 tons/day for the 5% biodiesel program to just over 2 tons/day for the cetane and California diesel programs that cover both on- and off-road diesel.
- NOx benefits range from a 3 ton per day increase for the 20% biodiesel program to roughly a 13 ton per day reduction estimated for the on- and off-road California diesel program.
- Biodiesel produces the least VOC and CO emissions benefit of all the diesel options and has a NOx disbenefit, which increases as the "bio" fraction increases.
- There are no measurable NOx benefits from diesel retrofit programs.
- None of the diesel options produce significant VOC emission reductions.

**Figure ES-3. Summary of Inventory Benefits of Diesel Programs VOC, CO and NOx in 2007**




Notes for Figure ES-3

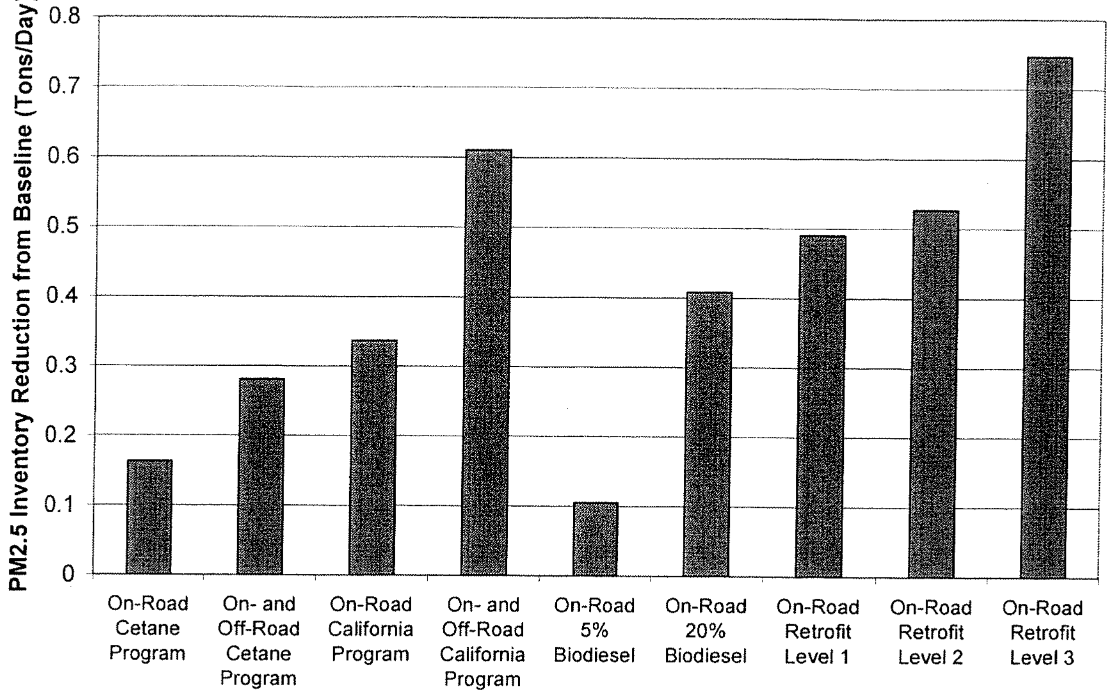
1. Each program was assumed to achieve 100 percent implementation or coverage over the 7-county SEMCOG region. As such, all applicable diesel engines would operate under the specifics of each program.
2. No data or equations were provided by EPA for estimating CO benefits from California Diesel, therefore, CO impacts for this fuel were not modeled.
3. Because available data for off-road bio-diesel benefits is inconclusive and very few retrofit technologies have been approved for off-road use, off-road emissions benefits were not modeled for these programs.

## Findings and Observations Regarding Diesel PM2.5 Emissions:

Figure ES-4 summarizes the 2007 PM2.5 exhaust emissions benefits from the various diesel options. Benefits were estimated relative to the Baseline mobile source inventory, which for PM2.5 in 2007 is estimated at 9.4 tons/day for all diesel equipment and vehicles.

- As with NOx, the largest PM2.5 reduction comes from California diesel, which yields over twice the benefit of the high cetane option.
- Overall, benefits range from roughly 0.1 tons per day for the 5% biodiesel program to nearly 0.8 tons per day for the Level 3 diesel retrofit program.
- On a percentage basis, the PM2.5 benefits range from 2 to 11 percent of diesel emissions.
- The diesel retrofit options show a comparatively high PM2.5 benefit. However, these values assume 100% implementation on all vehicles operating in the region, while surveys indicate only 36% of truck activity in the region is from centrally-fueled, local fleets.

Figure ES-4. Summary of Inventory Benefits of Diesel Programs
PM2.5 in 2007




Notes for Figure ES-4

1. For the purpose of this study, each program was assumed to achieve 100 percent implementation or coverage over the 7-county SEMCOG region. As such, all applicable diesel engines would operate under the specifics of each program.
2. Because available data for off-road bio-diesel benefits is inconclusive and very few retrofit technologies have been approved for off-road use, off-road emissions benefits were not modeled for these programs.

## General Findings and Observations:

In addition to the specific findings and observations by pollutant and fuel, some other noteworthy results to be considered in policy discussions that might follow this report are listed below.

- Currently available tools for estimating benefits of different fuels have limitations and, in some cases, predict very different results. Nonetheless, through careful application of model inputs and cautious interpretation of model outputs, a good understanding of the range of impacts of different fuel configurations was achieved and is summarized in this report.
- The vast majority of emission reductions from mobile sources between 2002 and 2007 (40% in VOC and 40% in NOx) will result from the phasing-in of existing federal regulations, most notably, more stringent vehicle emission standards and reduced sulfur in both gasoline and diesel fuel. Potential emission reductions from the fuel strategies studied are relatively small when compared to the decrease in the mobile source inventory and will decrease with time beyond 2007 as the overall mobile source inventory decreases.

- Generally, the gasoline fuel options produce higher VOC benefits while diesel options can produce the highest NOx benefits and also decrease PM2.5 emissions.
- Different fuels produce a wide range of benefits, and in some cases disbenefits, for each of the pollutants evaluated. Therefore, the best fuel option, or combination of options, will depend on which pollutants need to be reduced, how much reduction is needed, what it will cost, and when it can be implemented. The data in this report should be combined with other information as part of the policy decision on which new fuels, if any, to select.